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Field Experience with Four Portable VOC (Volatile Organic Compound) Monitors

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FIELD EXPERIENCE WITH FOUR PORTABLE VOC MONITORS

by

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ABSTRACT

This report discusses the field operation problems associated with use of four portable volatile organic compound (VOC) detection instruments in conducting Reference Method 21 VOC screenings. The report presents the results of the field trials and summarizes the ease of use of each instrument. Information on operational problems and recommendations are provided. Also included are discussions of the features that would make all portable instruments more reliable, durable, or convenient to use. Based on the data collected for this study, three of the instruments report similar leak rates in the facility where they were used.

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SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has issued performance standards and guidelines to limit emissions of volatile organic compounds (VOC) from several stationary source categories. These industries such as petroleum refineries, synthetic organic chemical plants, and natural gas processing plants emit significant quantities of VOCs from sources other than classical point sources into the workplace and surrounding atmosphere. These fugitive VOC emissions occur from valves, pumps, drains, pressure relief devices, etc. In order to reduce these fugitive emissions, EPA has promulgated regulations that require periodic monitoring of the potential leaking sources in order to identify leaking sources so they can be repaired. Specialized instruments are required since the leaking VOCs cannot normally be detected without them.

As described in 40 CFR 60, Appendix A, Reference Method 21 (RM 21), Determination of Volatile Organic Compound Leaks, there are technically feasible devices suitable for monitoring fugitive VOC leaks. These devices can be placed near possible points of emissions and will respond to releases of the organic compounds. Specific instruments suitable for this purpose include, but are not limited to, catalytic oxidation, flame ionization, infrared absorption, and photoionization detectors.

EPA has prepared a Technical Assistance Document (TAD) titled "The Use of Portable Volatile Organic Compound Analyzers for Leak Detection." The December 1983 report was prepared by Ralph M. Riggin of Battelle Columbus Laboratories for Roosevelt Rollins of the EPA under Contract No. 68-02-3487 (WA-18). The TAD describes in detail the four types of detectors and typical instruments. Additionally, it contains information on manufacturers of these instruments. Another useful document is titled "Summary of Available Portable VOC Detection Instruments," EPA-340/1-80-010, March 1980. This document also contains lists of manufacturers of portable VOC detection instruments.

Subsequent field use of portable VOC detectors has disclosed some instrument-specific problems such as undetected flame-outs, plugged orifices from dirt, high background readings due to chemical absorption on probe and tubing surfaces, high humidity effects, varying or lack of response, long response times, and calibration drift. The EPA, through its contractor, Research Triangle Institute, proposed that four instruments undergo field use to identify and document instrument-specific problems of the instruments used to conduct screenings following RM 21. The four instruments chosen do not represent all the available instrument types. Rather, they were selected for evaluation because they were in common use. Other types and brands of instruments are available, and the conclusions and recommendations in this report may not be applicable to all of them.

This report is to document the field operational problems encountered while using the four available instruments. The instruments were selected for use on the basis of their availability and because two of them have been frequently encountered in field use by PEI. A comparison of the manufacturers' specifications was made with the RM 21 test requirements and is shown in Table 1. Although some of the instruments did not appear to meet the RM 21 requirements, all the instruments were used and their field experience reported. No attempt was made to make a rigorous evaluation of each instrument or of RM 21. However, where possible, the requirements of RM 21 were met.

Under contract to the U.S. Environmental Protection Agency (EPA) and private clients, PEI has routinely conducted VOC screenings using the Foxboro* Century Systems Portable Organic Vapor Analyzer Model OVA-108 (OVA), following RM 21. The screenings have been required as part of various state and federal regulations. (Regulations encountered include 40 CFR 60 Subparts VV and GGG, Santa Barbara County Air Pollution Control District Rule 331, Bay Area Air Quality District Regulations Rules 18 and 25, and Louisiana Petroleum Refinery Fugitive Emissions Control Regulations.) Although various VOC screening instruments were used to develop the background information for the EPA standards and RM 21, the operational problems of using those instruments

*Registered trademark.

TABLE 1. REFERENCE METHOD 21 PERFORMANCE CRITERIA FOR FOUR INSTRUMENTS BASED ON MANUFACTURERS' DATA

Reference Method 21 section	Criteria	Acceptability by instrument			
		HNu	TLV	AID	OVA
3.1.1a)	Responds to compounds being processed	Yes[a]	Yes	Yes	Yes
3.1.1b)	Capable of measuring the leak definition concentration specified in the regulation[c]	No[b]	Yes	Yes	Yes
3.1.1c)	Capable of scale reading to ±5% of the specified leak definition	Yes[d]	Yes	Yes	Yes[e]
3.1.1d)	Equipped with a pump for continuous flow of 1/2 to 3 lpm	Yes	Yes	Yes	Yes
3.1.1e)	Intrinsically safe	Yes	Yes	Yes	Yes
3.1.2a)	A response factor for the individual compounds to be measured must be less than 10[f]	No[g]	Yes	Yes[h]	Yes
3.1.2b)	The instrument response time must be less than 30 seconds	Yes (5 sec)	Yes (3 sec)	Yes (2 sec)	Yes (2 sec)
3.1.2c)	The calibration precision must be ≤10% of the calibration gas value	Yes (<1%)[i]	Yes (<1%)	Yes (<1%)	Yes (<1%)

[a]The HNu reportedly does not respond to methane (the calibration standard used), ethane, and some other gases. It reportedly does respond to carbon tetrachloride which was present at one site.

[b]The HNu is not capable of measuring a 10,000 ppm concentration without first diluting the sample. No commercial dilution systems are known to be available that would permit using the HNu for field screening where the instrument must be calibrated on a 10,000 ppm methane or a hexane standard and also capable of measuring in the field 10,000 ppm concentration gases.

[c]Assumes a 10,000 ppm reading of methane. However, California regulations require reading a 75,000 ppm value.

(continued)

TABLE 1. (continued)

[d]The HNu maximum scale reading is 2,000 ppm. However, scale divisions are 100 ppm; therefore, it is readable to 5% of a 10,000 ppm standard.

[e]The OVA scale is logarithmic. At the upper end of the scale, the divisions are greater than 500 ppm. However, at lower readings, the scale divisions are less than 500 ppm.

[f]The response factor varied for each plant where the evaluations occurred, and a yes response indicates that in most of the plants the instrument response factors were less than 10. However, in one of the plants the response factors were greater than 10.

[g]The HNu is not capable of measuring a 10,000 ppm concentration without diluting the sample, and there is no known dilution system for field use with the HNu. Available information indicates the response factor for the HNu for methane, ethane, and propane is greater than 10.

[h]Assumes the same response factors as for the OVA since both instruments use the same type of detector. However, response factors for the AID were not determined.

[i]Based on use of the 48 ppm benzene calibration gas. No other calibration gases were available.

were not published. Therefore, this task was established to perform field screenings using four different available VOC screening instruments and document and report on their ease of use and the operational problems that occur during use.

The task was designed to conduct screenings under field conditions. Therefore, PEI obtained permission from facilities where we were working with our primary instrument, the OVA, to use the instruments listed below for VOC screening:

Foxboro Century Systems Portable Organic Vapor Analyzer Model OVA-108;

United Technology's Bacharach Instruments Model TLV Sniffer;*

Analytical Instruments Development, Inc., AID Model 712;* and

HNu Systems, Inc., Model PI-101.*

Brief descriptions of these instruments are contained in Appendix A.

The purpose of this report is to provide basic information on each instrument, how they were used, what operational problems were encountered during and between screenings, and the ease of use of each instrument in relationship to the other three. As part of the field use of each instrument, PEI collected the screening data on each instrument's response to various leaks in the facilities and compared the results. These data are summarized in Appendix B. The data were collected using the four instruments and following RM 21 as closely as possible. However, because of equipment problems (AID and OVA failures at some sites), the data are of limited usefulness in showing that the screening results are the same regardless of the instrument used.

In the course of the study, special attention was given to documenting operational problems and ease of use. Appendix C contains summaries of the daily and site instrument critique sheets used to record the instrument problems.

*Registered trademark.

SECTION 2

FIELD TRIAL METHODS

The instruments used represent three types of detectors. The OVA and Analytical Instruments Development, Inc., Model 712 (AID) are flame ionization detectors (FID). FIDs draw a gas sample into a combustion chamber where it is burned in a hydrogen flame. The combustion products produce charged ions. The number of charged ions and the type of chemical in the sample stream are empirically proportional to the concentration of the chemical in the sample stream. The charged ions cause a current flow in the detector where the number of flowing ions is proportional to the VOC concentration in the sample stream for the particular VOC under investigation. United Technology's Bacharach Instruments, Inc., Model TLV Sniffer (TLV) uses catalytic oxidation (such as a platinum-coated wire) and a Wheatstone bridge to detect resistance changes in the catalytic oxidizer electrode. The catalytic oxidizer causes the VOC (or other combustible) to burn, and the resulting released heat raises the temperature of the electrode. As the temperature is raised, the resistance in that portion of the Wheatstone bridge increases. As a result of the resistance change, the bridge circuit produces a signal proportional to the concentration of the combustible in the sample stream. The HNu Systems, Inc., Model PI-101 (HNu) uses a photoionization detector (PID). In this system, ultraviolet light is generated and strikes the organic molecules in the sample stream. When the ultraviolet light is absorbed, an ion is emitted from the molecule and collected on a detector. The number of ions collected is proportional to the VOC concentration. Each of these instrument types has its own unique characteristics. Appendix A presents more details taken from the manufacturers' operating manuals on the OVA, AID, TLV, and HNu. Other information on portable VOC instruments is contained in the report titled "The Use of Portable Volatile Organic Compound Analyzers for Leak Detection," December 1983, and prepared by R. M. Riggin of Battelle Columbus Laboratories.

There are other models and brands of VOC screening instruments available besides the four used in the field trials. More information on available VOC screening instruments may be found in two EPA documents: "Summary of Available Portable VOC Detection Instruments," EPA-340/1-80-010, March 1980; and "Evaluation of Potential VOC Screening Instruments," EPA-600/7-82-062, November 1982.

METHODS OF EVALUATION

The first step in the evaluation was to use the information reported by the manufacturer and compare each instrument's performance with the performance requirements in 40 CFR 60, Appendix A, Reference Method 21, Section 3. The comparison was used not to disqualify any instrument from use but to provide information on how the instrument could be used. The intent of the field trials was to develop information on the ease of use of these four instruments and to report on any operating problems encountered during their use. The evaluation is summarized in Table 1 and is based on information contained in the manufacturers' literature and other published sources.

While preparing Table 1, the following three points were raised:

1. The response factors for the TLV and OVA are published in two EPA documents. Those response factors differ from those published by the manufacturers. Since the OVA and AID operate on the same principle, it is assumed that they have the same response factors. However, even though the response factors published by the manufacturers of the OVA and AID are similar, they are not the same. No attempt was made to verify the manufacturers' information or to measure response factors for any of the instruments. We did not find any published response factors for the HNu; however, the manufacturer did publish relative sensitivity values which are related to response factors but cannot be directly converted to them. Most of the published response factors are for pure chemicals which may not be correct for use with various chemical mixtures encountered during screening. Additionally, the mixtures encountered in screening are poorly defined and change as the process stream moves through the facility, making determination of an appropriate response factor difficult.

2. The manufacture of the HNu suggests a method of detecting and measuring high concentration samples using dilution. Although a dilution probe is available for use with the OVA, no attempt was made to dilute samples or use any dilution probes. Previous experience with

the dilution probe on the OVA found it unsatisfactory since the calibration was unreliable, and satisfactory screening results could be obtained without using it on the OVA. PEI is unaware of any commercially available dilution system for the HNu that can be used while conducting RM 21 screenings.

3. The response factor is not normally used in determining whether or not a source is leaking. It is simply a measure of an instrument's responsiveness to the compounds in question and must be less than 10 to meet RM 21 requirements. At one plant the response factors for the compounds in the screening area were greater than 10. However, the instruments (OVA and TLV) would response to the compounds (published response factors for the OVA and TLV were approximately 20 and 30, respectively, for one of the compounds). Therefore, another instrument reading was chosen as the action level, and an instrument response of that value or greater was considered as a leak. The chosen value was selected to equate to a 10,000 ppm concentration of the compound being screened. For a compound with a response factor of 20, this equates to a 500 ppm reading on the instrument. If a compound had a response factor of 9.0, it would meet the requirement of RM 21, Section 3.1.2a. However, its actual concentration in order to achieve a 10,000 ppm reading on an instrument calibrated with methane as required in the Petroleum or SOCMI regulations would have to be 90,000 ppmv. At this concentration, many VOCs would flame out an OVA before giving a 10,000 ppm response and would not be considered as a leaking source. Therefore, the selection of an actual concentration of 10,000 ppmv is considered conservative.

Although the above points have possible serious implications about the applicability of the instruments' usefulness in conducting RM 21 screenings for compliance with appropriate regulations, they do not interfere with providing enough information to satisfy the project's intent. Therefore, these points were basically ignored, and the instruments were used in order to determine the information necessary to complete the field trials and report on the problems and ease of use of the instruments in the field. The above three points are considered part of the problems with the instruments' field use.

Only one of the instruments, the HNu, had a negative response to any of the performance criteria. However, the OVA is equipped with a logarithmic scale and does not have scale divisions of 500 ppm or less at the upper end of the scale (it does have scale division of less than 500 ppm at the lower end of the scale), so it technically does not meet the requirements of RM 21.

The next step was to formulate a method of evaluating the instruments. Because the chief goals of the study were to document and evaluate ease of use

and operational problems of these instruments, it was obviously necessary to use each instrument as much as possible. However, since the plants were being routinely screened with the OVA, PEI continued to use the OVA to screen the entire plant. Because of the time required to screen the whole facility only a part of the facility was used for the field trials. Operating time on the other instruments was, therefore, not equal to that on the OVA.

The OVA, TLV, and AID instruments were calibrated using a 9,970 ppmv methane-in-air certified calibration gas. Ambient air was used as zero air. The calibration gas was taken from a compressed gas cylinder into an inert bag. The bag was triple purged with the calibration gas before each use. The calibration gas in the bag was then used to calibrate the instruments. The bag sample was repeatedly attached and detached to the sample probe inlet until the instrument reading was stable at the calibration gas value without having to readjust the calibration dial. The meter reading was recorded on a calibration log. The calibration procedure was performed before and after each day's screening. Where appropriate, the calibration was checked at midday. No changes were made in the instrument settings and the instruments were not shut off until final calibration values were recorded.

With the HNu none of the lamps can be calibrated to a 10,000 ppm methane or hexane standard as supplied; the instrument is not sensitive to methane and a dilution system must be used to calibrate to hexane. Since no dilution system was available, none was used, and the instrument instead was calibrated with a 48 ppm benzene standard to verify the system was responding before it was used in the field trials. All three lamps were used.

RM 21 allows calibration using either methane or hexane. Methane in air was used rather than hexane in air because of the difficulty in obtaining a 10,000 ppm hexane in air standard and the reduced hazards (10,000 ppm methane in air is not explosive while 10,000 ppm hexane in air is near the lower explosion limit for hexane). A compressed gas cylinder containing 10,000 ppm hexane in air is near saturation. Therefore, obtaining reproducible concentrations of a calibration standard from a compressed gas cylinder is difficult because some hexane condenses out inside the cylinder and changes the volumetric concentration of the hexane in the air.

We conducted two types of operational tests with the equipment, a reliability check and field operations. In the reliability check, the instruments were charged and allowed to operate for several 8-hour periods. This test provided some assurance that the instruments could operate over an 8-hour period. In the field operations, all four instruments were used to screen a series of 200 to 300 sources. Following the screening, the instrument operator completed an evaluation sheet, reported any problems with the instrument, and provided general subjective comments on the instrument as a leak detection tool.

The log sheets collected during the evaluations are summarized in Appendix C.

EVALUATION SITES

The first of the four plants screened, Site 1, is a small, integrated refinery operation with approximately 3,000 sources subject to screening. For the instrument field trials, approximately 200 sources were selected, and each of the four instruments was used to screen those sources. Because of the difficulty of repeatedly locating the various sources, there were instances during the screening process when some sources were not screened with all of the instruments. This occurrence is reflected in the summaries contained in Appendix B. We anticipated that the leaking materials would be mostly methanes, ethanes, and propanes and suggest that this is the reason we obtained low responses on the HNu. The HNu did respond in a few cases to some leaks; however, the responses obtained on the HNu were all approximately 100 ppm, well below the leak level definition.

The second facility screened, Site 2, manufactures fluorocarbons used for refrigerants. The screening was limited to one of the three processing areas making fluorinated hydrocarbons F-11 and F-12. The screening was conducted predominantly in the reactor area; however, a number of sources from the purification process, including F-11 blend and weigh tanks, were screened. The only two VOCs that were present in the test area were carbon tetrachloride (a feedstock) and F-11. Approximately 150 sources were chosen for the evaluation.

The AID was not available for use at Site 2. Prior to the screening, the AID was operating properly. However, the instrument failed to ignite at the plant. The testing staff made numerous attempts to adjust the instrument in the field, including recharging the instrument with hydrogen and removing the detector and cleaning it, but all attempts failed. The instrument was eventually returned to the manufacturer, who found and repaired a hydrogen leak and readjusted the hydrogen flow rate.

The third facility screened, Site 3, is an integrated refinery with approximately 14,000 sources. The screening operation took place in one portion of the refinery where light hydrocarbons are combined to form heavier hydrocarbons. Most of the leaking materials in this area are octane and lighter aliphatics. Approximately 300 sources were chosen for evlauation in this facility. Only the AID, HNu, and TLV were used on the day of the evaluation because the OVA failed to operate properly. The OVA was subsequently returned to a manufacturer's representative who replaced the preamplifier. The HNu did not respond to any of the leaks within the test area.

Site 4 is a small natural gas processing plant. The plant receives sour natural gas from an offshore field. The gas passes through a slug separator to remove liquids then through an amine sweetening process. Some liquids are removed but only natural gas was present in the portion of the plant where the instrument field trials were conducted. Approximately 200 sources were chosen for evaluation. Only three of the instruments were evaluated since the HNu does not respond to methane, the only leaking substance in the evaluation area. Although methane is an exempt hydrocarbon, Santa Barbara requires a RM 21 leak testing program. The proposed NSPS regulations for new natural gas processing facilities do not address the fact that most leaks are methane or ethane.

SECTION 3

SUMMARY OF EVALUATIONS

Of the four instruments used in the field trials, the AID, HNu, and TLV were new or nearly-new instruments. The OVA is approximately 4 years old and has been used extensively for VOC screenings in many plants. It has been reconditioned once by Foxboro and repaired several times by various Foxboro manufacturers' representatives; in addition, field maintenance has occasionally been performed on the instrument. Prior to the field trials, the instrument had been in routine screening use in a refinery in Louisiana.

The field trials were designed to provide subjective comments on the instruments' performance. Table 2 summarizes the comments developed from the screenings.

The operator logs reveal some interesting information about the useability of the instruments. (These logs are summarized in Appendix C.) For example, the AID is equipped with a liquid crystal digital readout. This device has a fairly narrow viewing angle, and it was frequently impossible to observe the readout while moving the probe tip all around the source as required for proper screening. To compensate for this difficulty, the operator used a short, flexible extension made of plastic tubing on the end of the probe. The operator could then manipulate the flexible probe tip around the sample interface with one hand and still maintain a satisfactory viewing angle of the display. This modification, however, made the AID more difficult to use because both hands were required to control the instrument probe.

All the instruments except the HNu were equipped with some kind of probe filter, and these filters were always installed. However, we added to all the instruments a 2-in. length of plastic tubing loosely stuffed with glass wool to protect the probe from contamination by the greases and oils present at many sources. The instruments' responses were the same with and without the plastic tubing in place. We developed this modification during other screenings and incorporated it for this study as a matter of course. The tubing

TABLE 2. SUMMARY OF OPERATING PROBLEMS

Item	OVA	TLV	HNu	AID
Carrying strap	The best arrangement of the instruments evaluated.	No strap; instrument was carried by a handle that was sometimes inconvenient.	The strap was very narrow and after an hour of carrying was quite uncomfortable.	The strap was unpadded and, although reasonably wide, the edge of the strap became very uncomfortable after an hour of carrying.
Battery	Acceptable during period of evaluation.	Acceptable during period of evaluation.	Acceptable during period of evaluation.	Acceptable during period of evaluation.
Battery charger	Acceptable during period of evaluation.	Acceptable during period of evaluation.	Acceptable during period of evaluation.	Acceptable during period of evaluation.
Instrument readout	The analog readout with logarithmic scale was conveniently located in the probe and very easy to use.	The readout in the control unit was less convenient to read than on the probe but was acceptable. It required frequent scale changes that were somewhat inconvenient.	The readout in the control unit was less convenient to read than on the probe but was acceptable. It required frequent scale changes that were somewhat inconvenient.	The digital readout was difficult to read from an angle, and the frequency with which it had to be updated made selection of a reading value difficult.
Calibration knob or zero/span adjustment	The knob could not be secured. However, since it was located on the control module, which had a cover, it did not require securing.	The zero adjust knob (only adjustment) was located on the control module and could not be secured. It was easily and frequently bumped, requiring re-zeroing of the instrument, until it was secured with tape.	The zero knob was somewhat protected and was quite stiff to turn. It is located on the control module and did not require securing.	The calibration (zero and span) require a screwdriver to adjust. The response and level knobs had locks to secure them. All were acceptable.

(continued)

TABLE 2. (continued)

Item	OVA	TLV	HNu	AID
On/off and other controls	The controls are on the control module. The instrument and pump switches are easily moved (newer models have locking toggles). The handles on the hydrogen supply are too short (newer models have longer ones). The gas select knob was not used since span gases were used for calibration.	The on/off/standby, battery, operate, and range switch caused no problems.	The controls were acceptable.	The alarm, on/off switch, and the battery/AC/charge switch were frequently confused, which resulted in turning off the instrument instead of the audible alarm on several occasions.
Sample line and instrument umbilical	The sample line tends to kink after long use when the protective sleeve slips. The line could be longer. The electrical connector at the control module has been weakened and has shorted.	The sample hose could be longer. During the evaluation period, the hose developed a kink and would frequently pinch off, causing the pump to stall and the instrument to operate improperly.	The umbilical was too short.	The umbilical was too short.
Probe contamination	Since all the plants had some sources where the probe could get dirty, all units were affixed with a 2-in. long piece of Tygon tubing with a glass wool plug as a primary filter.	See OVA comments.	See OVA comments.	See OVA comments.

(continued)

TABLE 2. (continued)

Item	OVA	TLV	HNu	AID
Probe contamination (continued)	This flexible tip was also helpful when screening because it made it easier to get the probe tip close to the source interface.			
Probe assembly	The assembly was conveniently sized and not uncomfortably heavy. The alarm adjust knob on the back was broken off when the assembly was dropped.	The probe is very lightweight and easy to manipulate.	The assembly was quite heavy and very difficult to manipulate.	The assembly had a comfortable feel. However, the plastic bezel damaged during the second screening falls off frequently.
Audible alarms	The alarm cannot be heard in most plant environments. The ear plug was very uncomfortable and the operators did not wear it.	See OVA comments.	Not applicable.	See OVA comments.
Screening time	Very good; ~30 seconds per source.	Somewhat slow; ~45 seconds per source.	Unknown; no response to sources.	Very good; ~30 seconds per source.

is easily replaced and reduces time spent in the field cleaning the metal sample probes. The tubing was normally replaced on an as required basis which was fairly frequently. The replacement criteria was based on appearance of the tubing if there was any visible contamination on it it was replaced.

The TLV comes without a shoulder strap making it very awkward to use for screening. We used straps from the other instruments when screening with the TLV. Also, since the zero knob is easily moved, we used a piece of tape to secure it. This prevented us from having to constantly check and reset the instrument zero.

The OVA comes with one strap. However, after several screenings we realized that if it could be worn as a backpack, it would be easier to use, make the operator more mobile, and speed up the screenings. Therefore, we purchased a second strap from the manufacturer and wore the OVA as a backpack, using the two carrying straps as a shoulder harness. Since the OVA has a readout on the hand-held probe, this did not create any problem. However, when the instrument flamed out, relighting it was a little awkward since the operator had to either get someone else to press the igniter button on the case or let the case slip forward on the shoulders and stretch around to reach it.

The OVA has been used extensively, and a common problem encountered has been battery failure. After consultation with several technicians, we learned that the requirements for long battery life were frequent use with care not to overcharge or allow the battery to go into deep discharge. Since the instrument was used by many people on an irregular basis, no satisfactory solution to the battery problem was found. Therefore, we frequently replace the battery on the OVA. However, with regular use and maintenance, the battery problem should be minimal.

Our experience with the battery in the OVA highlighted the fact that the battery problem was really one associated with the battery type (rechargeable nickle cadmium batteries) and not the Century Systems battery. Basically, the nickle cadmium rechargeable batteries all require the same kind of treatment for long life; i.e., frequent use (regular discharging and recharging), protection from overcharging, and protection from deep discharge. Therefore, any device with rechargeable nickle cadmium batteries should be used with the same precautions to ensure long battery life.

The HNu did not detect any leaks. The HNu response was surprising, especially at Site 2, because this plant processes chlorinated hydrocarbons. Previous EPA reports indicated that the HNu would respond to chlorinated hydrocarbons. The chlorinated hydrocarbons, carbon tetrachloride and F-11, were present in pure form in the screening area, but the HNu did not respond to them even though it was properly calibrated on a 48 ppm benzene standard. We do not know why the HNU did not respond.

As a test of the HNu's response small samples of carbon tetrachloride and F-11 were taken from process sample drains after purging them. All three HNu detectors were used to see if any would respond to the two samples. Each probe was attached and the appropriate calibration settings dialed into the instrument. The probe tip was then lowered into a container of one of the compounds until the tip was about 1/2 inch from the liquid surface. This was repeated at least three times. A comment on the instrument's responses was then made.

In all cases, the HNu responded with a zero or slightly below zero reading when the probe tip was placed near the free surface of the two samples. Sometimes as the probe was brought near the liquid, an upscale response would occur but when the instrument reading stabilized with the probe tip near the liquid surface, it always indicated zero or below. The upscale responses were erratic and unpredictable with each probe.

During the screenings, we collected data on the leak rate over the same group of sources in four different plants. These data are presented in Appendix B. Although in some cases the data were collected using procedures that do not exactly follow RM 21 procedures and for sources that are not covered by federal regulations, the data still demonstrate how using different instruments produce similar results.

The screening at Site 1 resulted in leak rates of 8.60, 7.46, and 8.05 percent from the AID, TLV, and OVA, respectively (results for the HNu are not included). These are higher than the overall plant leak rate since the screening area was chosen to include as many leaking sources as practical.

At Site 2 three different people screened the area with two different instruments. The leak rates were 5.16, 5.16, and 5.16 percent with the OVA and 3.23, 3.23, and 2.58 with the TLV. At this plant the response factors for

the instruments were quite high (20 and 30, respectively). This is probably why the results do not agree well and points out that high response factors are undesirable.

At Site 3 the OVA was not operational during the evaluation; the preamplifier did not function on the day of the evaluation (the OVA had operated properly only two weeks earlier). However, data were available from a screening in the area approximately three months earlier. The plant personnel reported that there had been no attempted repairs of leaking sources in the area in that three-month interval and that the process was operating at the same level as when the OVA was used as when the TLV, AID, and HNu were used. The screening results were 4.93, 2.46, and 8.45 percent for the AID, TLV, and OVA, respectively. (The HNU did not respond to any leaks in the area.) The higher rate for the OVA is unexplained. The difference between the AID and TLV appears to be because of a lower response factor for the TLV than the AID. However, the area supposedly only contained methane, ethane, and propane which have very low response factors for both instruments.

At Site 4 the leak rates were 1.63, 1.09, and 1.63 percent for the AID, TLV, and OVA, respectively. The only leaking material at this plant was methane, and all three instruments were calibrated with a 10,000 ppm methane calibration gas which definitely seems to enhance the reproducibility of results among the instruments.

SECTION 4

DESIRABLE INSTRUMENT FEATURES AND RECOMMENDATIONS FOR FUTURE STUDIES

Rather than recommending improvements in each instrument, we have developed a description of the desirable features that should be included in a field screening instrument:

- The strap should allow for carrying the instrument on the back, out of the way, leaving the hands free for climbing, handling log sheets, and manipulating the probe and readout (assuming the readout is attached to the probe).
- The calibration controls should be located in the backpack and protected by the instrument case cover. All controls should have locks to prevent unintentional movement.
- The readout should be analog and use a logarithmic scale that ranges from 10 to 100,000 ppm. RM 21 must be modified to accept the resulting scale divisions.
- The readout should have a lock-and-hold reading capabilities and/or hold-highest-reading function switch.
- There should be provisions to use the instrument as a go/no-go detector with indicator lights to show whether the reading is above or below the calibration point.
- An igniter button should be located on the probe/readout if the instrument uses an FID.
- A series of status indication lights should appear on the probe/readout assembly to show if the instrument has sufficient battery charge and if it is responding.
- The sample line connecting the backpack and probe/readout should be at least 4 ft. long and very flexible.
- A holster should be provided for the probe/readout so that both hands can be freed for climbing and handling data sheets.
- The probe assembly should have provisions for frequent cleaning because the probe becomes contaminated with grease and other materials during the screening process.

- The system should be protected from the elements and be able to operate in light rain, high humidity, and high ambient temperatures.
- The system should protect the rechargeable battery from overcharging and deep discharge. Provisions should be made for easy battery removal and replacement. Ideally, the charging system should be capable of being left on charge at all times. There should also be an indication of when the unit is within one hour of being too weak to operate effectively. This would provide time to check the instrument calibration before the unit required recharging.
- The calibration system should allow for easy calibration to multiple calibration gases.

As screening instruments, all the instruments used could be improved. The above list of desirable features would enhance the usefulness of any of the instruments.

The object of a screening program is to identify leaking sources so that they can be repaired and thus reduce fugitive emissions. RM 21 and the associated regulations define a leak based on a specified instrument reading with the instrument calibrated with a specified calibration gas. The most commonly used definition is a 10,000 ppm response when calibrated with a 10,000 ppm methane calibration gas. This is really a go-no-go measurement and the exact instrument reading is not important as long as we know it is either above or below a calibration mark established by a certified gas. There is no requirement to measure the actual concentration.

The above is not a problem with the use of portable VOC instruments but must be recognized by those conducting screenings and using the results. The screening results are not meant to be a quantification of the leaking materials but a count of the leaking sources where the leaking source definition is based on a screening method. Keeping this in mind, to measure a leak we only need to be concerned that we have a certified calibration gas, an instrument that will consistently give the same reading when exposed to that calibration gas and an instrument that responds in a known way to the leaking gases. An ideal instrument for screening would be one that had only two indicators on it; i.e., a red light indicating a value above the calibration point and a green one for a value below the calibration point. This would require calibration with two gases: one slightly above the leak rate definition point and one slightly below.

It would be beneficial to field test other instruments. A March 1980 report, "Summary of Available Portable VOC Detection Instruments," EPA 340/1-80-010, on available VOC detection instruments should be updated to include current prices and to indicate whether or not the instruments meet the requirements of RM 21. Available and additional data on leak rates, repeatability of screening values, and response factors for VOC instruments should be assembled in a screening handbook to present the kinds of information necessary for a proper screening program. Information should be included on how to screen various types of sources, how to prepare log and repair sheets, response factors of various instruments, lists of typical compounds encountered in various types of facilities, etc. Screening procedures should be developed for organic materials with response factors greater than 10.

APPENDIX A

FOXBORO CENTURY SYSTEMS PORTABLE ORGANIC VAPOR ANALYZER MODEL OVA-108

The OVA consists of two primary units connected with an umbilical cord, as shown in Figure 1. It is designed to measure trace quantities of organic materials in air employing a hydrogen flame ionization detector similar to that utilized in laboratory gas chromatographs. The flame ionization detector is an almost universal detector for organic compounds although it is more sensitive to some organics than others. It has the sensitivity to analyze in the parts per million (ppm) range in air, and in the presence of moisture, nitrogen oxides, carbon monoxide, and carbon dioxide.

The instrument has broad application and can readily be calibrated to measure many organic vapors. The instrument has an adjustment so that the meter readout can be expressed on any reference calibration compound. However, the instrument responds to all the compounds present in the sample stream, and the meter reading is a measure of all the compounds in the sample stream in terms of the calibrant gas. Specific knowledge of the instrument response to the compound(s) must be known in order to determine the concentration of the compound(s). It has a single logarithmically scaled readout from 1 ppm to 10,000 ppm. It is designed for use as a portable survey instrument. The OVA is certified as intrinsically safe by Factory Mutual Research Corporation (FM) for use in Class 1, Division 1, Groups A, B, C, and D hazardous environments.

The OVA is designed to detect and measure VOCs found in almost all industries, including those manufacturing petrochemicals and engaged in natural gas transmission and distribution. It measures organic vapor concentration by producing a response to an unknown sample that is related to a gas of known composition to which the instrument has previously been calibrated. During operation, a continuous sample is drawn into the probe and transmitted to the detector chamber by an internal pumping system. The sample flow rate is

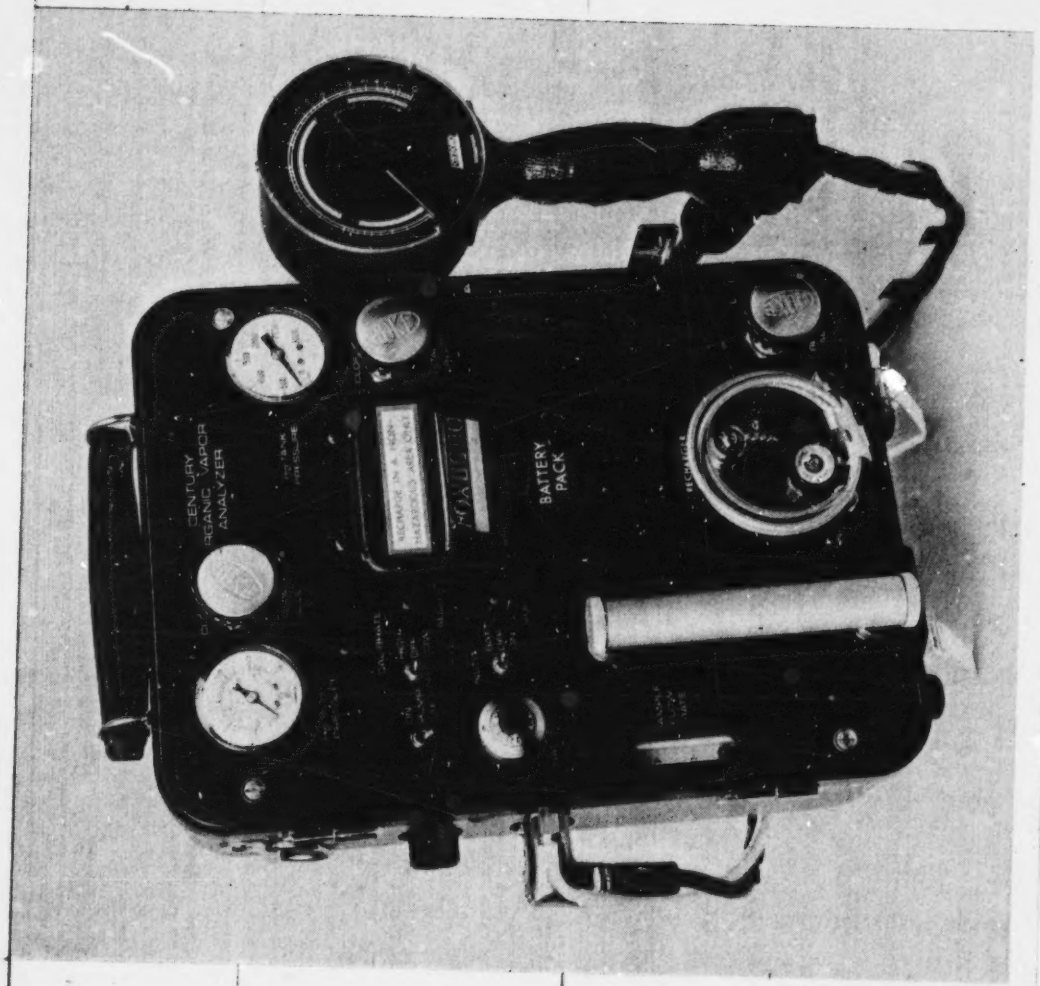

Figure 1. Portable Organic Vapor Analyzer OVA-108.

metered and passed through particle filters before reaching the detector chamber. Inside the detector chamber, the sample is exposed to a hydrogen flame that ionizes the organic vapors. When most organic vapors burn, they leave positively charged carbon-containing ions that are located by a negative collecting electrode in the chamber. The electric field that exists between the conductors surrounding the flame and the collecting electrode drives the ions to the collecting electrode. As the positive ions are collected, a current corresponding to the collection rate is generated on the input electrode. This current is measured with a logarithmic electrometer preamplifier that has an output signal proportional to the log of the input or ionization current. A signal conditioning amplifier is used to modify the signal from the preamp and to condition it for subsequent meter or external monitor display. The meter display is an integral part of the probe-readout assembly and displays a range of 1 to 10,000 ppm (1 percent) on the OVA.

The basic instrument consists of two major assemblies, the probe-readout assembly and the side pack assembly (see Figure 1). The output meter and alarm level adjustments are incorporated in the probe-readout assembly, which is operated with one hand. The side pack assembly contains the remaining operating controls and indicators, the electronic circuitry, detector chamber, hydrogen fuel supply, and electrical power supply. It is a quantitative instrument with sensitivity to 1 ppm methane and is capable of readouts from 1 to 10,000 ppm concentration by volume of methane in air.

Other major features include:

1. 250° logarithmically scaled readout;
2. internal electronic calibration;
3. less than 2-second response time; and
4. at the least, 8-hour service life for fuel supply and battery pack.

Internal two-point electronic calibration is provided for checking the instrument and supplying reference signals for setting up the gas select adjustment. A battery test feature shows charge condition to be read on the meter. Hydrogen flameout is signified by an audible alarm as well as a visual

indication on the meter. The instrument contains a frequency-modulated detection alarm that can be preset to sound at a desired concentration level. The frequency of the detection alarm varies as a function of detected level, giving an audible indication of organic vapor concentration. The instrument is designed for one-person, one-hand operation, and the entire unit weighs a total of less than 12 pounds, including fuel supply and battery. An earphone is provided for "only operator" monitoring.

During use, the operator can carry the side pack assembly on either the left or right side or as a back pack. The side pack assembly is housed in a high-impact plastic case and weighs less than 10 pounds. The probe-readout assembly can be detached from the side pack assembly and broken down for transport and storage.

In general, a hydrogen flame ionization detector is more sensitive for hydrocarbons than any other class of organic compounds. The response of the OVA varies from compound to compound but gives excellent repeatable results with all types of hydrocarbons; i.e., saturated hydrocarbons (alkanes), unsaturated hydrocarbons (alkenes and alkynes), and aromatic hydrocarbons.

The manufacturer has published in the operating manual typical relative reponse factors of various hydrocarbons to methane. The manufacturer defines the relative response factors as the read concentration in ppmv divided by the concentration in ppmv of the calibrant gas where the read concentration is for the compound listed in Table 3 prepared at the same concentration as the calibrated gas. Table 3 shows some of these factors as reported by the manufacturer (this is not the same as the response factor). The response factor is the reciprocal of the relative response factor.

Compounds containing oxygen, such as alcohols, ethers, aldehydes, carbolic acid, and esters give a somewhat lower response than that observed for hydrocarbons. This is particularly noticeable for those compounds having a high ratio of oxygen to carbon such as are found in the lower members of each series that have only one, two, or three carbons. When compounds containing higher numbers of carbons are analyzed, the effect of the oxygen is diminished to such an extent that the response is similar to that of the corresponding hydrocarbons.

TABLE 3. APPROXIMATE RELATIVE RESPONSE FACTORS FOR THE OVA FOR VARIOUS HYDROCARBONS RELATIVE TO METHANE

Compound	Relative response with methane as the calibrant gas
Methane	1.00
Ethane	.90
Propane	.64
n-Butane	.61
n-Pentane	1.00
Ethylene	.85
Acetylene	2.00
Benzene	1.50
Toluene	1.20

Nitrogen-containing compounds (i.e., amines, amides, and nitriles) respond similarly to oxygenated materials. Halogenated compounds also show a lower relative response as compared with hydrocarbons. Materials containing no hydrogen, such as carbon tetrachloride, give the lowest response; the presence of hydrogen in the compounds results in higher relative responses. Thus, $CHCl_3$ gives a much higher response than does CCl_4. As in the other cases, when the carbon to halogen ratio is 5:1 or greater, the response will be similar to that observed for simple hydrocarbons.

The typical relative response of various organic compounds to methane is shown in Table 4.

The OVA has negligible response to carbon monoxide and carbon dioxide. Thus, other organic materials may be analyzed in the presence of CO and CO_2. EPA has extensively measured response factors for the OVA. Three reports of interest are: "Response Factors of VOC Analyzers Calibrated with Methane for Selected Organic Chemicals," EPA-600/2-81-002, May 1981; "Response Factors of VOC Analyzers at a Meter Reading of 10,000 ppmv for Selected Organic Compounds," EPA-600/2-81-051; and "Response of Portable VOC Analyzers to Chemical Mixtures," EPA-600/2-81-110, June 1981.[1]

TABLE 4. APPROXIMATE RESPONSE FACTORS FOR THE OVA OF VARIOUS ORGANIC COMPOUNDS RELATIVE TO METHANE

Compound	Relative response with methane as the calibrant gas
Methane	1.00
Ketones	
Acetone	.60
Methyl ethyl ketone	.80
Methyl isobutyl ketone	1.00
Alcohols	
Methyl	.15
Ethyl	.25
Isopropyl	.65
Halogen compounds	
Carbon tetrachloride	.10
Chloroform	.65
Trichloroethylene	.70
Vinyl chloride	.35

ANALYTICAL INSTRUMENT DEVELOPMENT, INC., MODEL 712

The AID consists of two primary pieces connected with an umbilical cord, as shown in Figure 2. The instrument is designed for the continuous monitoring of organic compounds in air. The measuring technique used is hydrogen flame ionization. The system is self contained and completely portable. The AID is designed to meet Class 1, Division 1, Groups A, B, C, and D of the National Electrical Code. (As of the writing of the report, the manufacturer reports that the instrument has not been certified as intrinsically safe.) Some of the controls, most of the electrical circuits, the battery pack, the hydrogen cylinder, flow control system, and pump are located in the side pack, which is normally carried over the shoulder by the attached shoulder straps. Figure 3 shows the controls located on the top of the side pack, and Figure 4 shows the controls on the bottom of the side pack. The umbilical cord contains the gaslines and the electrical connections between the side pack and the gun. The gun contains the flame ionization detector, the electrometer

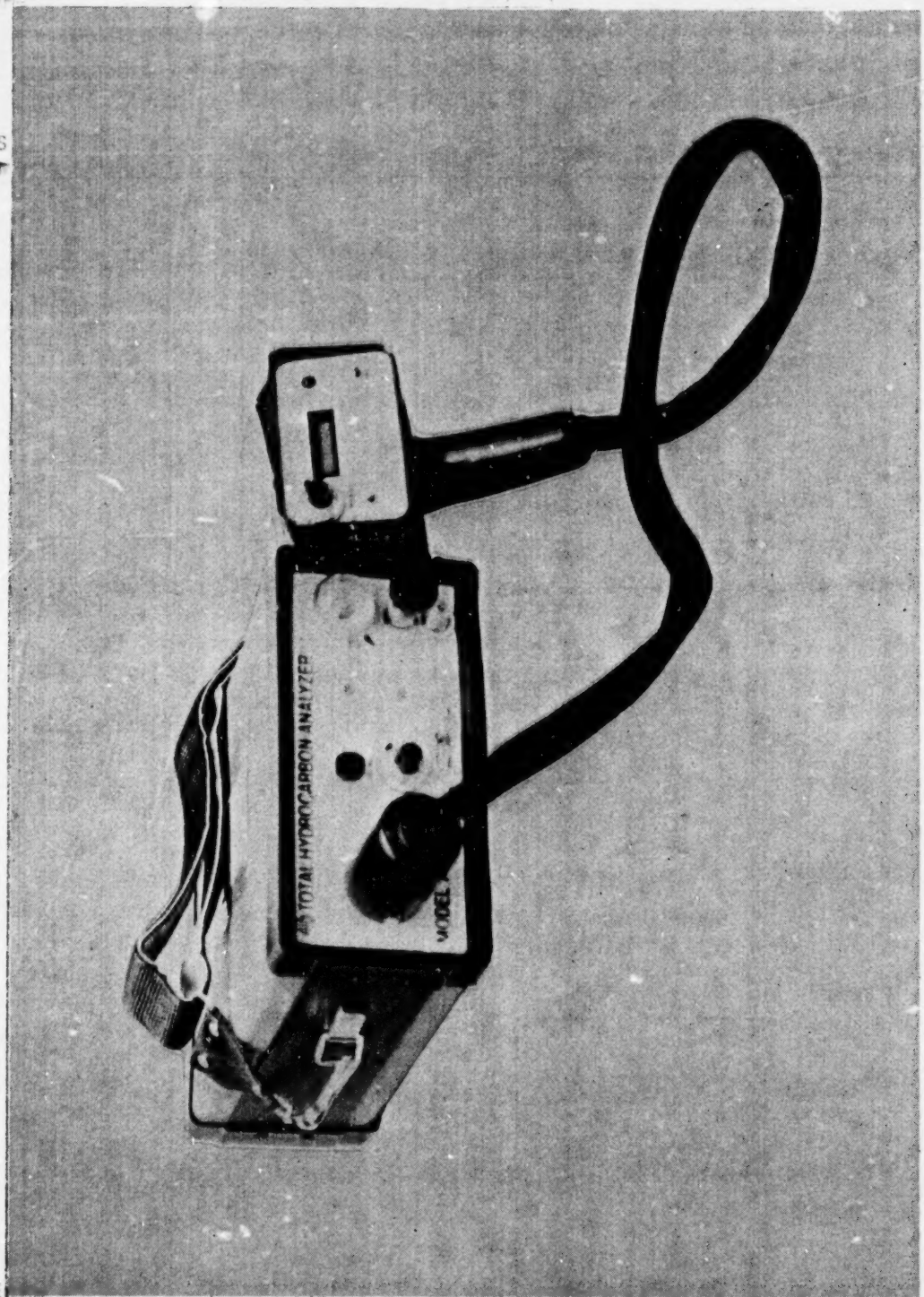

Figure 2. Analytical Instrument Development, Inc., Model 712.

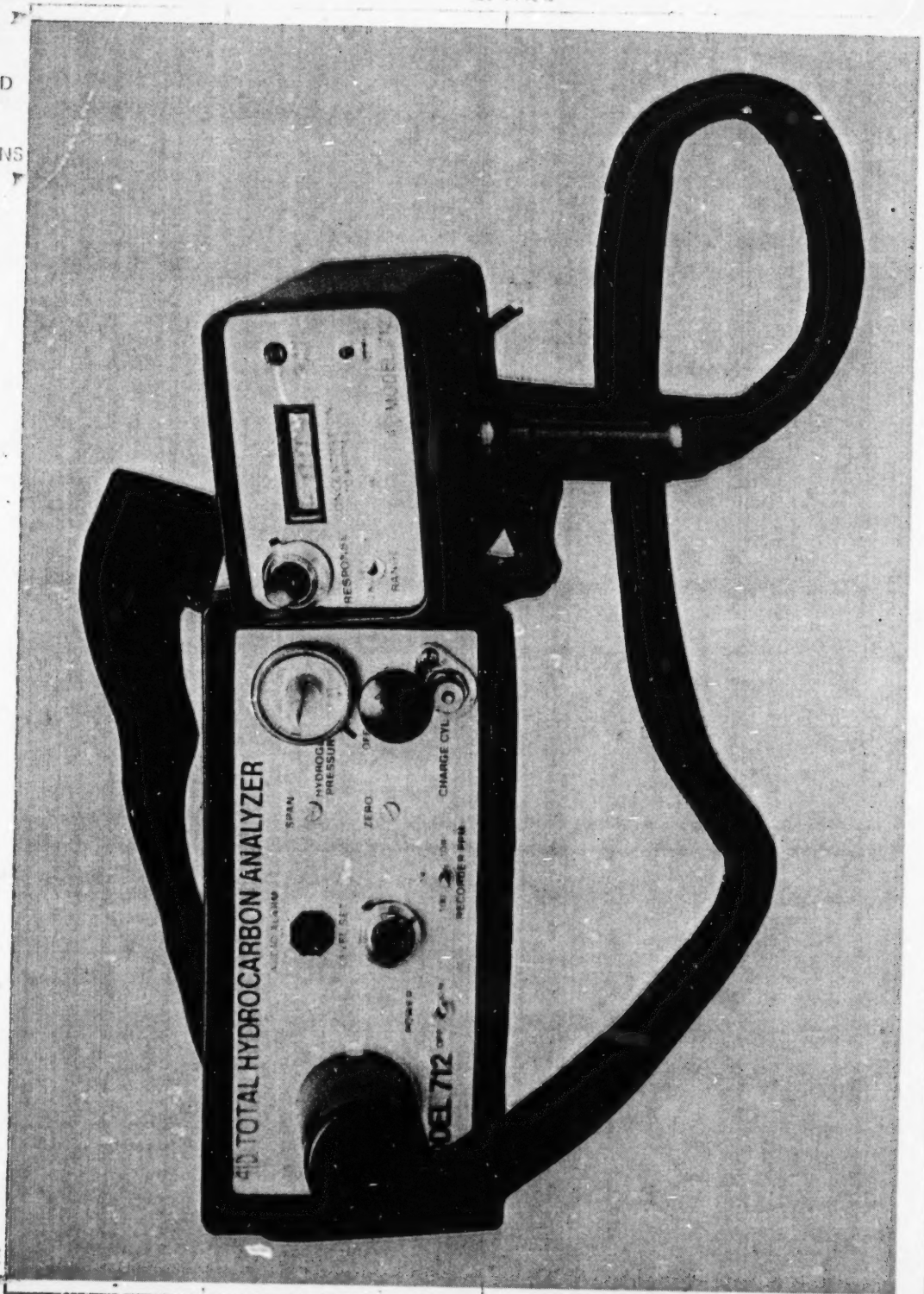

Figure 3. Controls located on the top of the AID side pack.

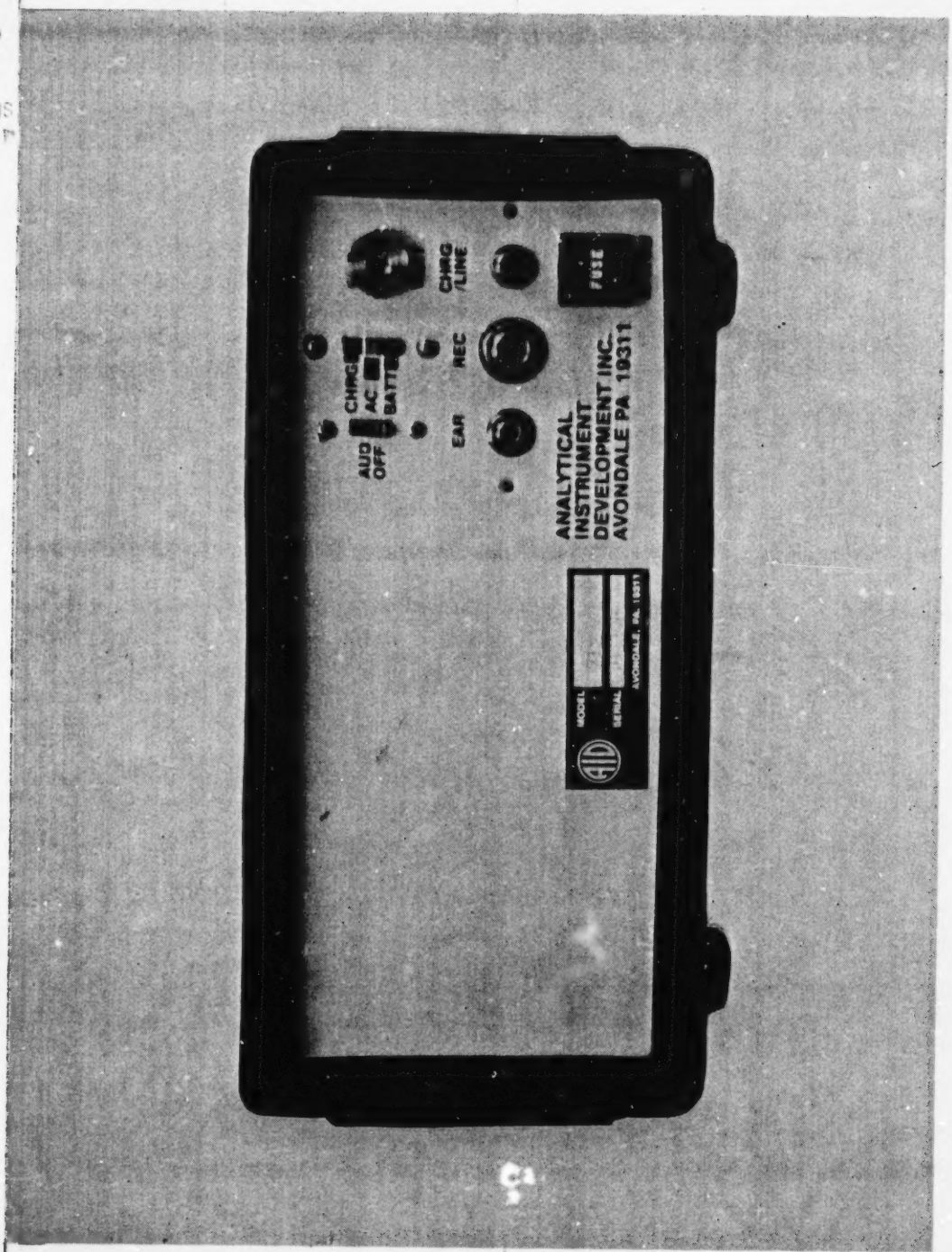

Figure 4. Controls located on the bottom of the AID side pack.

amplifier circuit, the digital readout and its circuitry, the sensitivity control and range switch, and the ignitor circuit and flameout indicator. The gun is carried in one hand and directed toward the sample to be analyzed.

Sample air is drawn into the flame ionization detector through a short length of stainless steel tubing. The air sample does not come in contact with the sampling pump until after the sample passes through the flame ionization detector and, thus, has been measured. The electrical signal from the flame ionization detector is amplified and presented in the digital readout which shows the concentration in ppm when the instrument is calibrated. There are two ranges: on the "X1" range the concentration of the sampled gas is read directly in ppm; on the "X10" range, the value shown on the readout must be multiplied by 10 to obtain the concentration of the sampled gas. All the readings displayed on the digital readout must be multiplied by 10. Thus, the reading 0 to 200 ppm on the "X1" range is actually 0 to 2,000 ppm, and on the 110 range the reading 0 to 2,000 ppm is actually 0 to 20,000 ppm.

The analyzer incorporates two separate flameout indicators. If the flame in the FID goes out, a small indicator light beside the digital readout is illuminated. In addition, an audible alarm sounds from the side pack. Following a flameout, the values of the readings generally become very low or even negative. Thus, the readings themselves provide a possible third indication of flameout.

The AID is provided with a variable concentration level alarm. If the concentration exceeds the level set on the alarm, a buzzer sounds. This permits monitoring for a predetermined concentration level of VOCs without continuous observation of the digital readout on the analyzer. The alarm adjustment potentiometer can be set anywhere between 0 and 10,000 ppm. When the digital readout indicates a reading above this level, the alarm sounds. A switch is available to disable the alarm when the instrument is being calibrated. This defeats the alarm circuit, both for flameout indication and for readings above the set point on the alarm circuit. A flameout will still be indicated, however, by the small red indicator light located to the side of the digital readout. The switch affects only the audible alarm.

Immediately above the range switch in the gun panel is the response control, which changes the gain of the amplification system and can be used to

reproduce various response factors for different materials in the AID. Normally, it is calibrated with methane when the response control is set at 100. Higher settings on this dial provide greater sensitivity for the instrument, and these settings are then used for the materials whose responses are less than the response obtained for methane. Lower numbers provide less sensitivity and are used for materials with higher responses. For RM 21 screenings, this dial would be set for methane or hexane and not changed.

The zero control compensates for the background current in the detector when no organic material is present in the sample. The zero adjustment is made to provide a zero readout when sampling zero air. The span control is used to adjust the readout of the system to provide the proper ppm readout for methane when presented with a known methane standard and the response control on the gun is set at 100.

The response factors listed in Table 5 are the numbers (the actual concentration in ppmv divided by the reference concentration in ppmv as reported by the manufacturer) by which the reading must be multiplied to give the correct concentration in ppm for that particular VOC, assuming the AID was calibrated correctly against methane as a standard. The lower the number of the response factor, the more sensitive the AID is for the material.

TABLE 5. APPROXIMATE RESPONSE FACTORS FOR THE AID OF VARIOUS VOCs RELATIVE TO METHANE

Compound	Response factor
Methane	1.00
Propane	1.30
Butane	1.04
Hexane	0.87
Benzene	0.48
Toluene	0.65
Ethanol	2.4
Isopropanol	0.75
Methyl ethyl ketone	0.90
Methyl isobutyl ketone	0.85
Chloroform	2
Carbon tetrachloride	10
Trichloroethylene	1.3

As Table 5 shows, the hydrocarbons have approximately equal responses on the AID versus methane standards. This means that the AID is giving about the same response for each mole or volume ppm. The aromatic hydrocarbons show slightly greater sensitivity than do the aliphatics. As can be seen, the introduction of chlorine into the molecule significantly reduces the sensitivity of the detector system for the molecules. The size of the molecules increases the effects of chlorine substituted into it. These effects are most notable in one- and two-carbon molecules. The substitution of oxygen into the molecule also reduces sensitivity for the one- and two-carbon molecules. Again, it should be pointed out that these response factors are approximate and will vary somewhat among individual instruments. However, on a given instrument, these will remain constant over time.[2]

BACHARACH INSTRUMENTS TLV SNIFFER

The TLV consists of a hand-held control module with a light sample line and metal probe attached, as illustrated in Figure 5. The TLV is housed in a brushed-aluminum and blue plastic case. The instrument weighs 5-1/2 lb and measures 8 x 6-1/2 x 3-1/4 in. A front panel contains a meter reading directly in ppm and a control knob for range selection and zero setting of the indicating meter pointer. Figure 6 shows the front of the TLV. The side panels of the instrument provide plugs and connectors for an air sample probe, earphones, battery charger, and recorder. Removal of 10 screws holding the plastic cover to the rigid aluminum case gives access to batteries and calibration adjustment controls located within the interior of the case. The TLV has been certified as intrinsically safe by the Factory Mutual Laboratories for use in hazardous areas designated Class I, Divisions 1 or 2 by the National Electrical Code.

The TLV air sampling system consists of a short intake connection leading directly into an interior aluminum air chamber holding the detector, a 6-in. length of tubing connecting the chamber and a miniature sample pump, and a 3-in. length of tubing leading to an exhaust port on the left side of the instrument case.

The combustible gas detector consists of an active catalyst-coated resistance element to oxidize combustible gas and an identical second resistance

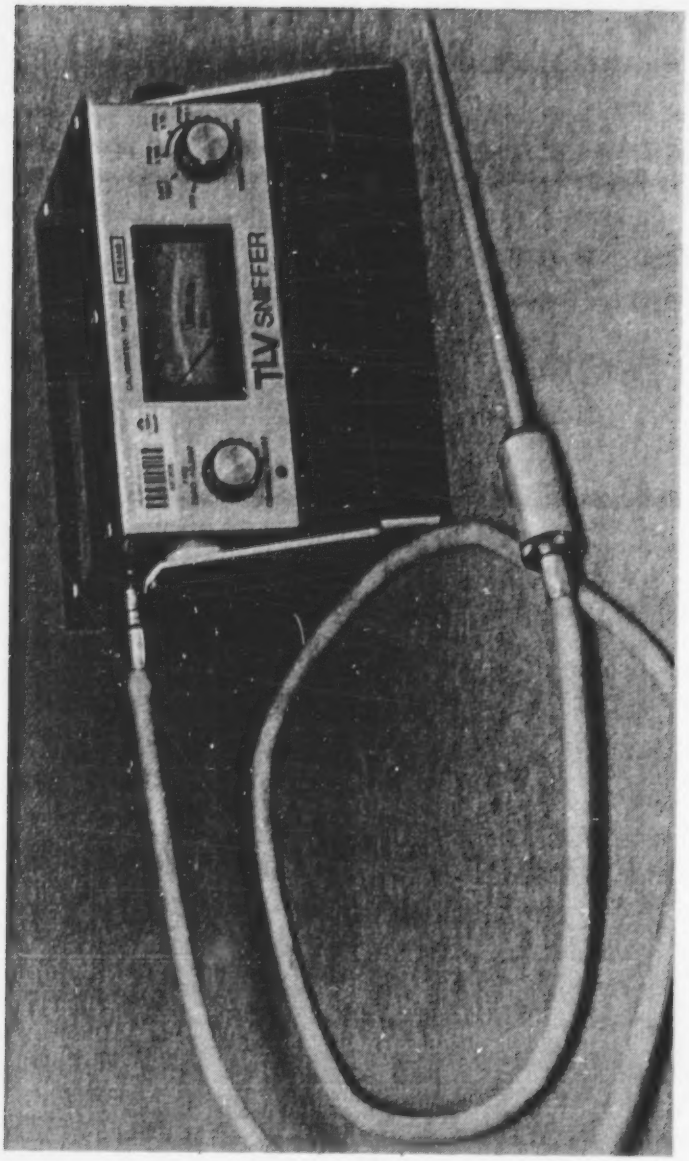

Figure 5. TLV.

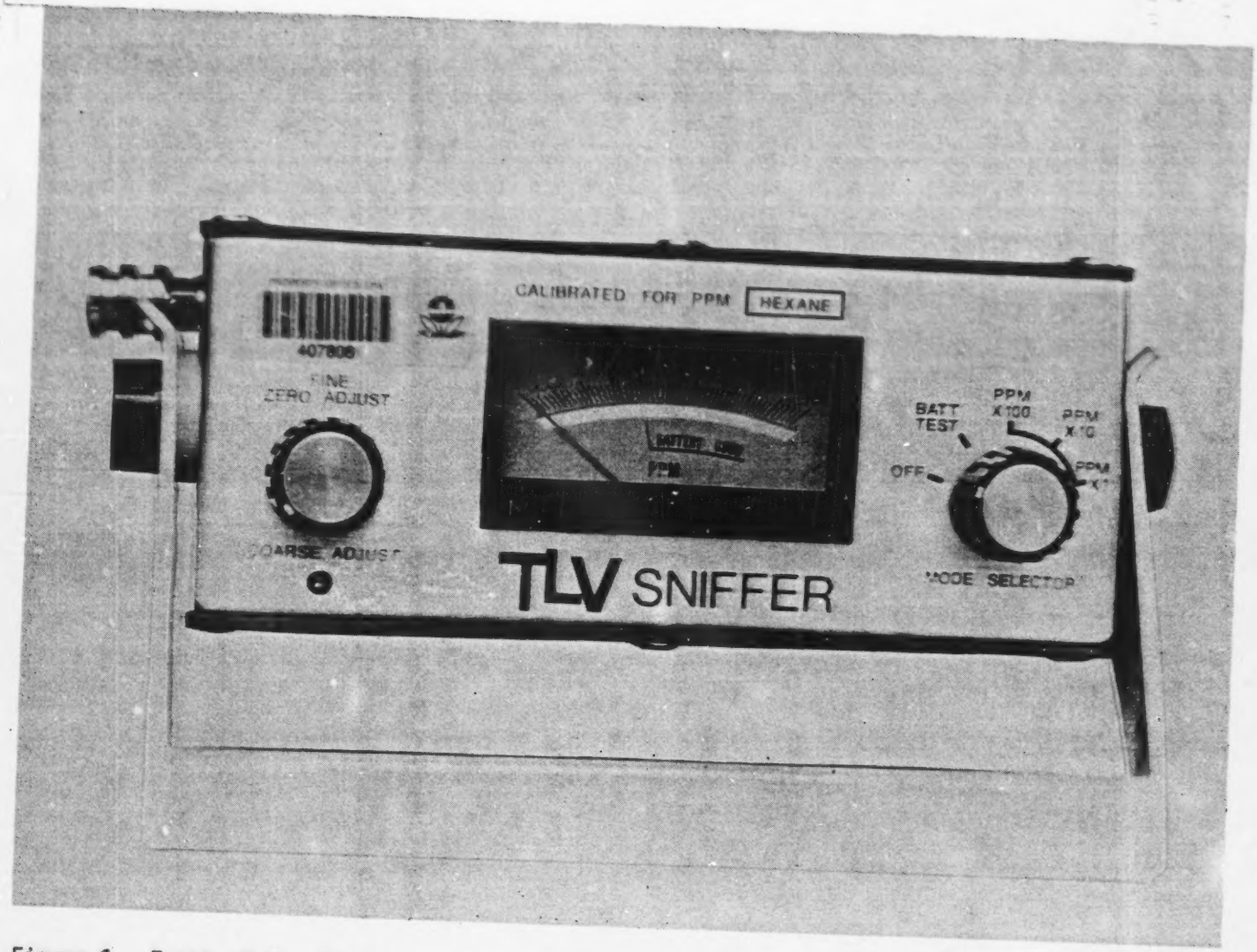

Figure 6. Front of the TLV.

element without the catalyst coating that provides a reference resistance. Since both operate at approximately equal temperatures, only changes in gas content of sampled air cause differences in resistance between the two to produce signals to the meter and gas alarm circuits. Both the catalyst-coated (active) element and the reference element are incorporated in a Wheatstone bridge circuit in such a way as to produce an electrical output proportional to their differences in resistance. Because changes in air sample temperature and humidity affect both active and reference elements equally, the electrical signal output is proportional to the heat transferred to the sensor element, which is proportional to the heat of combustion and concentration of the compound in the sample of air (expressed in volumetric terms as ppm). However, sudden changes in humidity may affect the zero reading on the X-1 range. The instrument should, therefore, be zeroed at the same relative humidity prevailing during use by using clean ambient air instead of prepared air (dried compressed air).

An audible alarm will sound at a preset gas concentration level. The alarm response is controlled by amplification of the difference between the gas concentration signal level and an internal reference voltage.

The TLV circuitry and meter provide readings from 0 to 10,000 ppm in three range settings. The meter readout is scaled as 0-100 in 2 percent increments. The amplifying circuits provide three decade settings, so the meter readings can represent 0-100, 0-1,000, and 0-10,000 ranges. Each range setting requires an easily made adjustment of the ZERO ADJUST control knob on the instrument front panel to set the meter indicating pointer to zero. Span adjustments for full-scale pointer deflection within each range are made periodically as necessary by means of three gain potentiometers located within the instrument.

The extent to which meter readings correspond to actual ppm of combustible gases in sampled air depends upon: (1) the internal electrical stability of the instrument; (2) proper calibration of the instrument on gas mixtures of known concentration; and (3) purity of the air sample used for meter pointer zero setting.

Hexane gas is commonly used for factory calibration and subsequent in-service recalibrations of the TLV. According to the manufacturer, the ppm

TABLE 6. MULTIPLYING FACTORS FOR CONVERTING PPM METER READINGS OF HEXANE-CALIBRATED INSTRUMENTS TO PPM CONCENTRATIONS OF OTHER GASES[3] (Approximations)

Gas detected	Factor	Gas detected	Factor
Acetone	1.50	Hydrogen sulfide	18.60
Acetylene	1.78	Isopropanol	1.59
Acrylonitrile	1.54	Methyl ethyl ketone	1.60
Benzene	1.02	Methane	1.58
1,3-Butadiene	1.52	Methanol	3.71
Butane	1.04	Methyl acrylate	3.37
Butyl acetate	2.08	Methyl chloride	4.02
Carbon disulfide	5.92	Methyl chloroform	4.44
Carbon monoxide	5.11	Pentane	1.04
Cyclohexane	1.02	Perchloroethylene	13.66
Ethane	1.36	Propane	1.14
Ethanol	1.90	Propylene	1.30
Ethyl acetate	2.22	Styrene	2.25
Ethyl ether	1.30	Tetrahydrofuran	1.41
Ethylene	1.38	Toluene	1.03
Ethylene oxide	2.05	Trichloroethylene	6.40
Heptane	1.05	Vinyl acetate	2.00
Hexane	1.00	Vinyl chloride	2.24
Hydrogen	1.45	o-Xylene	1.64

concentrations of gases other than hexane with instruments calibrated for hexane are determined by multiplying the ppm meter reading by the factor for the gas detected as listed in Table 6.[3] The table values are equivalent to the response factor referred to in RM 21.

HNu SYSTEMS, INC., MODEL PI-101

The HNu consists of two units, a side pack with all the controls and an interchangeable hand-held unit with the fan and detector connected by an umbilical cord to the side pack. There are three flame and detector assemblies available for the unit. Each one has a different lamp (sensor) for use with different groups or types of chemicals. The three lamps are 9.5, 10.2, and 11.7 ev. Each lamp will have a different calibration setting and a different group of compounds for which it is most sensitive. The HNu has been certified as intrinsically safe by Factory Mutual Laboratories for use in hazardous areas designated Class 1, Division 2, Classes A, B, C, and D. Figure 7 shows

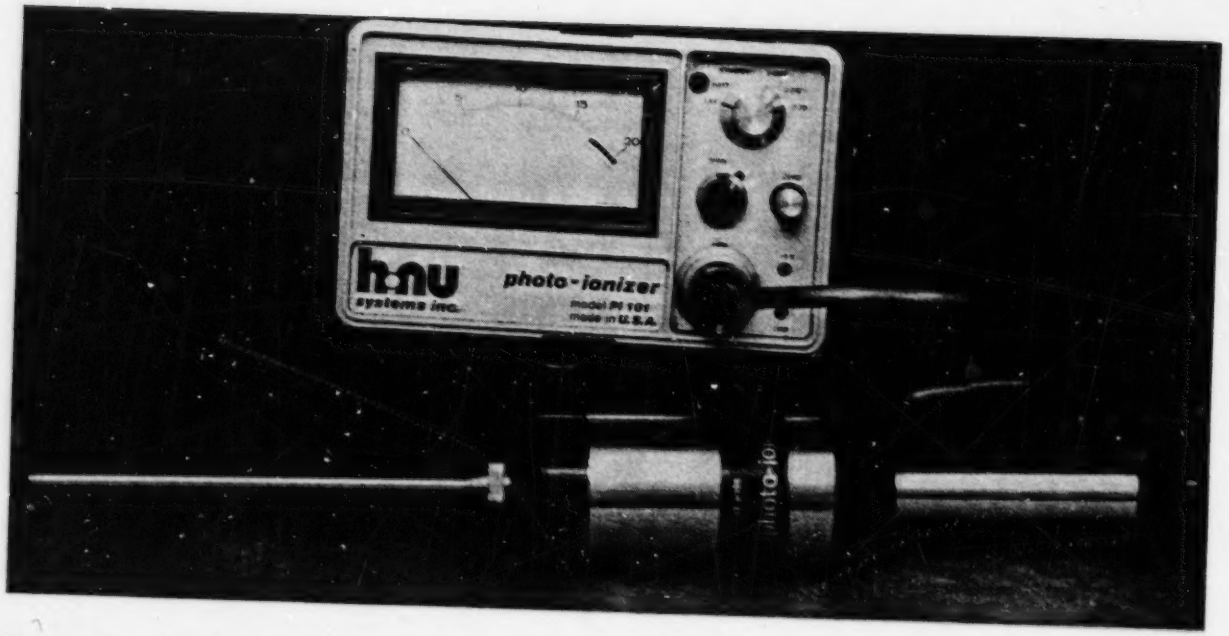

Figure 7. HNu Systems, Inc., PI-101.

the assembled instrument and Figure 8 shows the instrument controls and readout.

The HNu has been designed to measure the concentration of trace gases in many industrial or plant atmospheres. The analyzer employs the principle of photoionization detection (PID). This process is termed photoionization because the absorption of ultraviolet light (a photon) by a molecule leads to ionization via:

$$RH + h\upsilon \rightarrow RH^{+} + e^{-}$$

where RH = trace gas

$h\upsilon$ = a photon with an energy $\geq$ Ionization Potential of RH

The sensor consists of a sealed ultraviolet light source that emits photons energetic enough to ionize many trace species (particularly organics) but which do not ionize the major components of air such as O_2, N_2, CO, CO_2, or H_2O. A chamber adjacent to the ultraviolet source contains a pair of electrodes. When a positive potential is applied to one electrode, the field created drives any ions formed by absorption of UV light to the collector electrode where the current (proportional to concentration) is measured.

To minimize adsorption of various sample gases, the ion chamber, made of an inert fluorocarbon material, is located at the sampling port, and a rapid flow of sample gas is maintained through the small ion chamber volume.

The analyzer will operate either from a rechargeable battery for more than 10 hours or continuously from the AC battery charger. A solid-state amplifier board in the probe and a removable power supply board in the readout module enable rapid servicing of the unit in the field.

The instrument was designed to measure trace gases over a concentration range from less than 1 ppm to 2,000 ppm. The manufacturer states that higher levels of various gases (to percentage range) can be measured by diluting the sample with clean air to a concentration of less than 500 ppm. This is generally within the linear range of the instrument, and if the measured concentration is multiplied by the dilution ratio the correct concentration in the stream can be determined. No attempt was made to use this technique during any of the field trials.

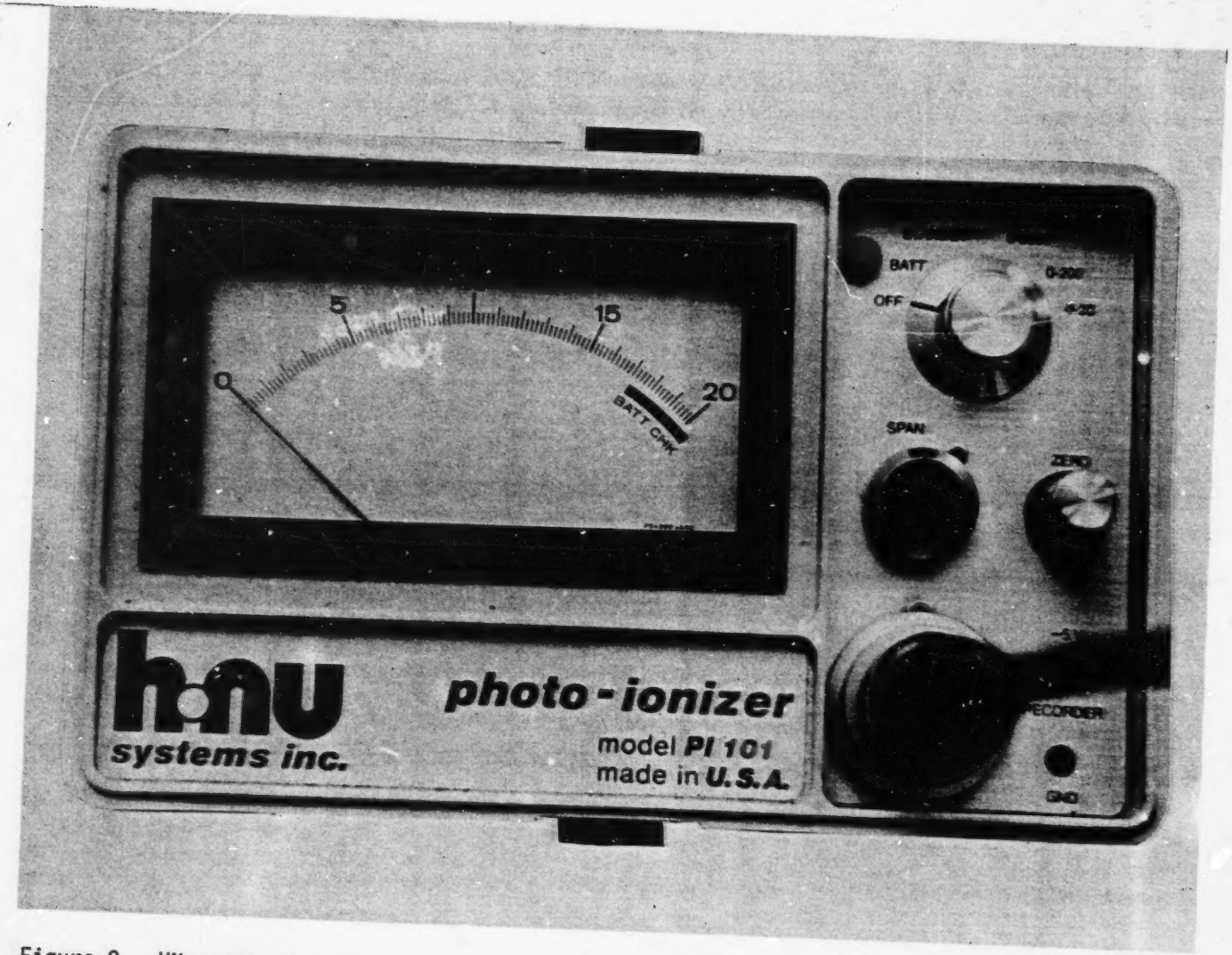

Figure 8. HNu controls and readout.

If the probe is held close to AC power lines or power transformers, an erroneous reading may be observed.

The instrument is equipped with an automatic solid state battery protection circuit. When the battery voltage drops below ~11 volts, the circuit will automatically turn off the power to the instrument. This protection circuit prevents deep discharging of the battery and considerably extends the battery life. If the instrument is unintentionally left on overnight, the battery will be unharmed because of the battery protection circuit.[4]

APPENDIX A REFERENCES

1. Foxboro Analytical Division of Foxboro Company. Instructions and Service Manual, Century Systems Portable Organic Vapor Analyzer Model OVA 108, MI2R900AD. Undated.

2. Analytical Instrument Development, Inc. Model 710 Portable Total Hydrocarbon Analyzer. Undated.

3. United Technologies Bacharach. Bacharach Instruction Manual, TLV Sniffer, Instruction 23-9613, Revision 1, September 1982.

4. HNu Systems, Inc. Instruction Manual for Model PI-101 Photoionization Analyzer. 1975.

APPENDIX B
SUMMARY OF FIELD SCREENING SHEETS AT FOUR SITES

TABLE 7. SUMMARY OF SOURCES WITH ONE OR MORE READINGS OVER 10,000 PPMV EVALUATED APRIL 26-27, 1984
SITE 1

Tag number	Instrument readings					
	AID	TLV	OVA	HNu 9.5	HNu 10.2	HNu 11.7
11701	OS[a]	OS	50,000	0	0	0
11731	OS	OS	FO	0	0	0
11732	15,000	OS	FO	0	0	0
12001	OS	1,000	NS	0	0	0
12022	OS	NS	NS	0	0	0
12041	12,000	8,800	FO	0	0	60
12047	OS	2,200	40,000	0	0	60
12101	OS	OS	75,000	0	100	100
12112	660	100	150	0	0	100
12119	315	1,800	10,000	0	100	110
12121	110	0	300	0	0	100
12125	170	200	100	0	0	100
12603	0	400	1,000	0	0	100
12604	1,400	0	500	0	0	80
12606	OS	OS	FO	100	100	100
12629	OS	NS	100	0	100	0
12641	0	0	100	0	0	100
12645	1,500	7,000	75,000	0	100	80
12654	1,500	0	900	0	0	90
12677	0	NS	FO	0	0	0
12700	OS	OS	FO	0	0	0
12810	OS	OS	FO	0	0	0

(continued)

TABLE 7. (continued)

Tag number	Instrument readings					
	AID	TLV	OVA	HNu 9.5	HNu 10.2	HNu 11.7
12817	OS	OS	FO	0	0	0
12865	OS	OS	FO	0	0	0
12907	OS	OS	FO	0	0	0
12924	OS	OS	FO	0	0	0
12926	18,000	OS	FO	0	0	0
12958	OS	OS	FO	0	0	0
12959	OS	OS	FO	0	0	0
Total sources	221	228	236	226	223	219
Leak rate, %[b]	8.60	7.46	8.05	0	0	0

[a]NS = Not screened.
OS = Off scale.
FO = Flameout.

[b]Based on sources with a 10,000 ppm response for the AID and OVA and a 6,000 ppm response for the TLV.

TABLE 8. SUMMARY OF SOURCES WITH ONE OR MORE READINGS OVER 10,000 PPMV EVALUATED MAY 10, 1984
SITE 2

Tag number	Instrument readings							
	OVA			TLV			AID	HNu; all 3 lamps
	SJ	JA	JL	SJ	JA	JL		
2019	FO[a]	FO	FO	2,000	2,000	300	N/A	0
2130	1,000	FO	L	700	300	2,000	N/A	0
2139	1,400	1,500	1,200	300	800	500	N/A	0
2172	600	1,100	700	200	400	200	N/A	0
2791	500	600	500	250	200	300	N/A	0
2795	FO	FO	FO	1,600	1,600	1,800	N/A	0
2805	1,200	1,000	1,100	500	700	600	N/A	0
2811	2,000	1,500	1,800	1,400	500	900	N/A	0
Total sources	155	155	155	155	155	155		
Leak rate, %[b]	5.16	5.16	5.16	3.23	3.23	2.58	N/A	0

[a]FO = Flameout.
L = Leaker.
N/A = Not available. The AID failed to operate and could not be used.
SJ = Skip Jones.
JA = Jack Allen.
JL = Justin Lejeune.

[b]Based on sources with a 500 ppm response.

TABLE 9. SUMMARY OF SOURCES WITH ONE OR MORE READINGS OVER 10,000 PPMV EVALUATED MAY 30, 1984
SITE 3

Tag number	Instrument readings			
	AID	TLV	OVA[a]	HNu; all 3 lamps
9035	13,000	4,000	NL[b]	0
9048	10,500	3,000	NL	0
9151	11,000	3,500	NL	0
9162	FO	6,800	NL	0
9280	FO	6,000	L	0
9281	FO	OS	L	0
9283	18,000	4,600	NL	0
9286	10,000	1,100	L	0
9290	FO	OS	L	0
9292	FO	OS	L	0
9294	FO	5,300	L	0
629	FO	OS	NL	0
3677	FO	0	Unknown	0
9401	FO	OS	L	0
9027	0	0	L	0
9033	490	0	L	0
9034	3,000	600	L	0
9036	4,500	1,200	L	0
9059	5,600	1,400	L	0
9062	3,000	1,400	L	0
9065	800	100	L	0
9067	6,500	2,600	L	0
9146	8,000	1,800	L	0
9166	1,500	0	L	0

(continued)

TABLE 9. (continued)

Tag number	Instrument readings			
	AID	TLV	OVA	HNu; all 3 lamps
9177	6,800	3,700	L	0
9178	900	0	L	0
9179	0	0	L	0
9282	100	0	L	0
9400	400	0	L	0
9416	0	0	L	0
9427	700	200	L	0
Total sources	284	284	284	284
Leak rate, %[c]	4.93	2.46	8.45	0

[a]OVA based on screening on 2/29/84, except for source 629, which is based on screening 5/22/84. The process operation is reportedly the same during the time of all screenings, and there was reportedly no maintenance performed on any of the equipment.

[b]FO = Flameout.
NL = Nonleaker, <10,000 ppm instrument response.
L = Leaker, ≥10,000 ppm instrument response.

[c]Based on sources with ≥10,000 ppm response on the OVA and AID or a 6,000 ppm response for the TLV.

TABLE 10. SUMMARY OF SOURCES WITH ONE OR MORE READINGS OVER 10,000 PPMV EVALUATED JUNE 21, 1984
SITE 4

Tag number	Instrument readings		
	AID	TLV	OVA
1530	12,000	0	0
1532	OS[a]	OS	75,000
1533	3,000	0	0
1559	500	0	0
1565	0	0	75,000
1585	0	0	9,000
1589	0	400	3,000
1615	680	0	0
1633 Flange	10,000	6,000	10,000
1637	800	0	0
1638	1,000	200	3,000
1641	5,000	2,000	0
1643	0	0	3,000
Leak rate, %[b]	1.63	1.09	1.63
Total sources (134 valves, 50 flanges)	184	184	184

[a]OS = Off scale.

[b]Based on sources with a 10,000 ppm response for the OVA and AID and 6,000 ppm response for the TLV.

APPENDIX C

SUMMARY OF COMMENTS FROM FIELD EVALUATION SHEETS

Tables 11 and 12 are composite summaries of the comments from the daily and site evaluation sheets. These comments are summarized in the report in Section 3.

TABLE 11. SUMMARY OF COMMENTS FROM DAILY INSTRUMENT CRITIQUES

Number of evaluation sheets: 29

1. Date of operation: 4/25/84 through 6/19/84.

2. Persons making evaluation: Robert Ressl, Stan Lueck, Justin LeJeune, Skip Jones, Jeff Hall, Jack Allen.

3. Instrument: HNu (with 9.8, 10.7, or 11.2 bulb)___, OVA-108___, TLV___, or AID___. (ALL)

4. Period of operation (use 24-hour time): 2-9 hours.

5. Was instrument on continuously or intermittently during the period of operation? Continuously except for accidental shutoffs.

6. Operational or screening location (plant name, process unit, etc.):

   Hercules, CA; Goleta, CA; Calvert City, KY; and Lake Charles, LA.

7. Names of all individuals using instrument during period of operation.

   Same as 2.

8. Number of sources screened or sampled (indicate the location or number of data log sheets or attach copies of the log sheets): 200-300.

9. Indicate location of calibration log sheet or attach copies for calibration before operation. N/A

10. Indicate location of calibration log sheet or attach copies for calibration after the period of operation. N/A

11. Instrument scales used: Low X Medium X High X

12. Report the calibration settings of the instrument used for the AID, OVA-108, and HNu. Varies

13. PROBLEMS: (Indicate "yes" answers only. Lack of a response is considered a "no.")

		Yes
a.	Any problems with initial or final calibrations?	6
b.	Any problems with calibration knobs?	9
c.	Any flameouts of instruments?	13

(continued)

TABLE 11. (continued)

13. (continued)	Yes
d. Any problems with stability of instrument readings?	13
e. Any problems with instrument background readings?	3
f. Any problems with instrument response time?	15
g. Any problems with weak battery or battery failure?	7
h. Any mechanical problems?	3
i. Any failures with the electrical components?	1
j. Any failures of the sample hose?	6
k. Any failures of the electrical connectors between the probe and the instrument?	1

14. For all "yes" answers to Item 13, explain in detail the particular nature of the problem and how it was resolved.

a. During calibration of the AID on a 9,970 ppm methane standard, had problems in adjusting to a correct value because readout updated so frequently. Also had to set calibration to 200 versus 100 recommended by the manufacturer (3 responses).

The HNu calibration was not as indicated on the sample gas supplied. The lamp window was cleaned as suggested but the result was the same.

The TLV could not be calibrated to a 10,000 ppm reading. The 10,000 ppm standard showed as 6,000 ppm.

b. Tape down the zero adjust knob on the TLV (9 responses).

The AID calibration setting was other than recommended by the manufacturer.

c. AID and OVA flame out on high concentrations (6 responses).

AID tended to flame out frequently and was often hard to relight and keep lit (3 responses).

The AID flameout light is impossible to see in bright sunlight.

(continued)

TABLE 11. (continued)

14. (continued)

The OVA flameouts posed little problem since it was easily relit.

The AID would not stay lit and could not be evaluated.

d. AID is difficult to read at an angle and the display changes too quickly (9 responses).

TLV does not seem to pick up all leakers.

The HNu needle responds strangely because of a weak battery.

The HNu was slow to respond if at all. When it did respond, it would peak, then drop back to zero reading (2 responses).

The TLV readings are not in accordance with the OVA readings.

e. With the OVA, where leaks were detected close to the background, it was difficult to distinguish them since instrument was showing a high background (100 ppm) (3 responses).

f. Slow response of the TLV (13 responses).

The HNu response was slow, if it responded at all (2 responses).

The HNu response was slow and would peak, then drop to a zero reading.

g. When the TLV was turned on, battery checked OK but after only a couple of hours of screening, noted erratic response. Battery check showed low battery. Therefore, screening results are doubtful (2 responses).

The operating manual says a battery charge for the TLV will last 6-8 hours. This may be too short for a long screening day.

The HNu battery checked OK but within an hour in the field was weak and instrument responded erratically (2 responses).

When the TLV battery became weak, the audible alarm went off. The instrument had been responding strangely for about 10 minutes before the alarm was heard. Therefore, it had probably gone off and was not heard because of the noise in the plant.

A weak TLV battery seemed to cause even slower response.

(continued)

TABLE 11. (continued)

14. (continued)

h. The AID needs a shade over the red flameout light so it can be read in bright sunlight.

The HNu carrying strap is uncomfortable.

The AID probe cover came off in shipping.

i. The AID would not work 2 days after the screening and was returned to the manufacturer for service. The manufacturer reported that the detector was contaminated with a brown coating identified as a sulfite.

j. The TLV sample hose has a tendency to kink (6 responses).

The OVA sample line crimped near the metal "L." The outer protective sleeve was slipped over the crimp and that seemed to prevent it from recurring.

k. The electrical connector between the probe and the side pack on the HNu is hard to turn during detachment and hard to align when attaching.

15. ANY OTHER COMMENTS:

The OVA was the easiest, most comfortable instrument to use, and the double strap back pack configuration made it very easy to use.

The OVA is quite heavy; however, the two straps make it much easier to carry and use.

The OVA needs a wrist strap or holster to hold the hand-held unit to free the operator's hands for climbing and handling log sheets.

The two shoulder straps and analog meter on the OVA made it very easy to use, and its response was very fast in relation to the other instruments.

When OVA first lit off, it read off scale and took several minutes to get back on scale.

There should be some way to lock and hold the highest reading on the AID.

The AID single strap was uncomfortable.

The AID was easy to use except for noted problems.

(continued)

TABLE 11. (continued)

15. (continued)	
	The switches on both ends of the AID side pack were inconvenient and resulted in turning the instrument off instead of the alarm.
	The AID umbilical is too short to allow full reach.
	The AID readings should be stabilized.
	The light weight of the TLV is very desirable.
	The TLV sample hose was awkward to use (3 responses).
	It was inconvenient to have to look away from the probe to read the instrument with the TLV.
	The TLV needs a carrying strap (5 responses).
	The TLV probe was easy to handle (2 responses).
	The TLV needs some way to store the probe and hose, freeing the operator's hands.
	The TLV is slow and would take longer to screen with.
	The HNu can only read up to 2,000 ppm but even on the worst leaks it would not read higher than 150 ppm.
	The HNu probe is uncomfortable to use (3 responses).
	The HNu did not respond to any of the compounds in the area (2 responses).
	The HNu was quite awkward to carry for any length of time.
	The HNu is very difficult to climb ladders with.
	On the TLV, HNu, and AID, the low voltage connector on the battery charger is of a type that has caused problems with other similar battery chargers.
	The audible alarm on the OVA, AID, and TLV cannot be heard in most plants.

TABLE 12. SUMMARY OF SITE CRITIQUES

1. Identify instrument used:

   HNu 3
   OVA 5
   TLV 5
   AID 5

2. Sketch the arrangement of the instrument as used and show any problem areas:

   Sketches not shown - modifications discussed in report Section 3.

3. Describe ease of use in relationship to the other instrument(s) used at the evaluation site.

	Ratings: 1st	2nd	3rd	4th
OVA	5			
TLV		2	3	
AID		3	1	
HNu				2

   The TLV was light and easy to carry but very slow.

4. Describe any problems in using the instrument to comply with Reference Method 21 procedures:

   OVA - None.

   AID - The calibration was difficult because of the changing display (2 responses).

   TLV - There are no calibration adjustments. Consequently, the instrument reading on the 10,000 ppm methane standard is noted and a scale conversion factor can be used to approximate actual readings as methane (3 responses).

   HNu - Can't calibrate to 10,000 ppm standard (2 responses).

   The instrument didn't respond to the chemicals in the screening area.

5. Describe any problems with handling the instrument:

   OVA - None.

   AID - The readout was difficult to read from an angle (2 responses).

(continued)

TABLE 12. (continued)

5. (continued)

AID - (continued)

The instrument was very heavy with the single strap arrangement (3 responses).

TLV - No shoulder strap makes carrying the instrument difficult and the sample line will crimp and shut off the sample flows (2 responses).

The sample line was cumbersome (3 responses).

HNu - The probe was awkward to handle (3 responses).

6. Describe any signs of damage that the instrument shows as a result of the use at the evaluation site.

OVA - None.

TLV - Kink in sample hose (2 responses).

HNu - None.

7. Describe any recommendations for modifications in the instrument design or function:

OVA - Use with two straps and wear as a back pack.

Develop a holster to hold the hand-held unit when not in use.

AID - The instrument needs a better strap (3 responses).

Make the umbilical longer.

Change the display.

Reduce how fast the digital display changes readings and shield the flame and light so it can be seen in bright sunlight.

TLV - The instrument needs a shoulder strap (3 responses).

Need a more durable and powerful battery pack and faster response.

Add capabilities to conduct field calibration.

HNu - Make the instrument respond to more chemicals (2 responses).

(continued)

TABLE 12. (continued)

8. Describe the instrument recharging procedure for the next day's use:

   ALL - Charged overnight.

9. Describe any problems with the hydrogen supplies or the power packs:

   OVA - None.

   AID - None.

   TLV - None.

   HNu - The instrument appeared charged when the screening started; however, after a short time of screening, the battery went dead.

10. Describe how the calibration gases were used:

    OVA, AID, TLV -

    A bag of a 10,000 ppm methane in air standard was prepared by filling and purging the bag three times. Then the bagged standard was attached to the instrument and the calibration set. The instrument was detached and reattached to the bagged standard gas several times until the readings were stable.

    HNu - Calibrated using 48 ppm standard only.

11. Any other comments:

    OVA - The instrument failed to operate on 5/30/84. The instrument manufacturer's representative replaced the preamp in the detector.

    AID - Concept and design seem practical. However, problems intrinsic to the instrument need to be solved.

    TLV - The battery charge did not last long enough.

    HNu - The instrument did not respond to the chemicals being measured.